LIGHTNING VERSUS COMPUTERS (or Bolts vs. Bytes): A SURVEY OF LIGHTNING INDUCED ELECTRICAL/ELECTRONIC PROBLEMS AT FT. STEWART, GA

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INTRODUCTION

Ft. Stewart, Georgia is located in a zone of high thunderstorm activity, with Spring and Summer seasons displaying near daily storm development. There are occasional occurrences during the rest of the year. Base operations at Ft. Stewart, GA have been significantly disrupted by lightning-induced upsets of electrical and electronic equipment. On post the majority of the lightning-induced problems have been occurring in equipment connected to Local Area Networks with a few telephone circuits having been affected. In almost all circumstances the equipment has experienced complete failure due to physical damage of electronic components. Board level replacement is required. In response to lightning-induced disturbances on the training ranges a policy of shutting down the electrical systems on the multi-purpose range complex (MPRC) has been effected.

USACERL personnel visited Ft. Stewart to survey some of the problem areas on base. Survey topics included: base geography, soil conditions, computer network topography, electrical and telecommunications grounding, and computer network hardware. In general, the survey was concerned with locating deficiencies that would create an environment that could allow lightning-induced electronics problems to occur. Particular areas of concern identified to the USACERL survey team by Ft. Stewart personnel at the time of the visit included: the cantonment/garrison area computer network, networked computers used for training at Evans Air Field, the range control office/target control center, and the Directorate of Public Works (DPW) office complex, all at Ft. Stewart; and Hunter Army Air Field.

This paper provides a summary of the survey, a rudimentary analysis of lightning-induced problems, an outline of actions intended to reduce the magnitude of the problem, and recommendations for future work which will lead to clarification, reduction and/or elimination of these problems.

SURVEY

The USACERL survey team and personnel from the DPW and the Directorate of Information Management (DOIM) discussed the lightning problems experienced at Ft. Stewart and examined electrical power systems and computer communications networks in the following areas:

Cantonment area: DPW facilities plus Buildings 1, 3, 4, 6, 8, 25, 627, 624, 620, 623, and 1003;
Evans Air Field: "Thicknet" network;
Range Control: Building 7901.

Additionally, a brief visit was made to Hunter Army Airfield where a DPW representative was interviewed to discuss lightning problems at that location.

The survey team made soil resistivity measurements at three locations on Ft. Stewart and earth-ground system resistance measurements on the electric power and the telecommunications systems at Building 627. Building 627 had experienced the greatest number of lightning-related failures during the year.

DOIM personnel at Ft. Stewart supplied the USACERL survey team with an occurrence history database containing information on lightning related computer system failures at Ft. Stewart. Database entries included the following: building, type of network connection, number of occurrences, and history. Number of occurrences was reported for the previous ten month period, January through October.

The survey team was also given two failed input/output (I/O) boards. On each board an integrated circuit (IC) chip had failed catastrophically (either burned or blown up).

OBSERVATIONS

The following is a summary of the observations made and data collected during the survey.

Ft. Stewart DPW: A commercial power line protection system had recently been installed at the DPW complex. The system and associated grounding was examined by the survey team. This protection system includes: Metal Oxide Varistors (MOVs) on the electrical power lines at the building's service entrance to conduct electrical power transients to ground and thus prevent them from entering the building; transient protection modules on equipment power inputs; and ground rods for these protectors. This system should provide a reasonable degree of protection from power line transients. The biggest deficiency is the grounding. Telecommunications and electrical power grounds are not interconnected, except through the soil. Additionally only a single ground rod is currently used at each location. Based on soil conductivity measurements made by the survey team, a single rod may not give a low enough resistance to earth to provide adequate lightning protection and certainly not low enough to provide satisfactory interconnection of the telecommunications and power grounds.

Ft. Stewart cantonment area computer network: This network consists of fiber optic trunk lines with conversion electronics (concentrator) to copper conductors at various locations. Intra-building and some inter-building communications use multi-pair copper conductors. A standard RS-232C interface is used to connect a concentrator with a computer's serial port. Five lines of the RS-232C interface are used in this implementation: receive data, send data, data terminal ready, carrier detect and ring indicator. The network multi-pair copper wiring is very similar to telephone system wiring with carbon block protectors (signal wire to ground through carbon block) used to provide transient protection at a building's entry. The protection block typically is grounded to earth using a single ground rod. A number of network hardware failures were identified by DOIM personnel at various points in this system, including a significant number of serial port and conversion electronics lightning-induced failures.

Ft. Stewart Evans Air Field: At this location a "Thicknet" system is used for network support to the battle simulation group. A "Thicknet" system is a computer network system which uses a relatively "thick" coaxial cable (RG-8 or larger) as the network backbone. This coaxial cable is tapped at specified locations for connection to individual computers. In this case, the large cable is routed above the ceiling through two buildings, the control tower building and an adjacent classroom building. A recent lightning strike to the control tower resulted in lightning current being either conducted to, or induced onto the ungrounded "Thicknet" cable and causing extensive damage to a number of network computers. Since that time, based on the recommendation of the network manufacturer, a single ground rod has been installed and connected to the "Thicknet" cable at the control tower end.

Ft. Stewart range control & target control electronics: Range control (Building 7901) was visited and lightning related problems at this building and with target control electronics were discussed. The building's electrical power service entrance had recently been upgraded. Along with the upgrade a new ground rod was installed. The antenna towers were not adequately grounded and the antenna cables were not grounded at all. The target control electronics are "hit" by lightning frequently; actually it is the cable which runs from the firing location to the target which is hit. There have been instances when the lightning stroke created pinholes in the cable. Lightning-induced earth currents can also affect the target control electronics. Since the target control electronics use 4 to 20 milliampere current control lines, too great a current could cause equipment burn-out.

Hunter Army Airfield: A general discussion of lightning problems at Hunter took place with the chief of the facilities engineering division. There have been infrequent problems at Building 1024 where some of the computers have gone out. There have been no problems since the project to upgrade the grounding at the Hunter DPW had begun.

Ft. Stewart soil conductivity and earth-ground resistance measurements: Soil conductivity measurements were made at three locations on Ft. Stewart using a Ground Resistance Meter. The measurement method produced the average soil conductivity to a 2.4 meter (8') depth. The measurements were made in the open area between buildings 627 and 624, near the reviewing stand at Cottrell Field, and inside the south corner (the 90 degree turn) of the access road leading to the buildings at Evans Air Field. The latter location appeared to be a relatively undisturbed area while the other two areas have been subjected to excavating, filling and grading. The measured values were:

Between Buildings 627 & 624	6.6×10^{-4} mhos/m
Cottrell Field	1.1×10^{-3} mhos/m
Evans Air Field	7.1×10^{-3} mhos/m.

At all locations the soil was damp because it had been drizzling for at least 18 hours before the test. All areas were quite sandy with the least sandy being at Evans Air Field.

The earth-ground resistance of both the electrical power and the telecommunications systems at Building 627 were measured. The earth-ground resistance of the electrical power system (green wire ground as measured from the electrical entry breaker box) was 1.67 ohms. The power system ground appeared to consist of two nominal 4-inch buried metal conduits at least 15 meters long which conveyed the electrical conductors from the power pole into the building. No other grounding method was visible on the electrical power system.

The earth-ground resistance of the telecommunications system was 1,230 ohms. No ground rod connection was visible for the telecommunications system. The ground wire leaving the protector box went down the same nonconducting PVC (polyvinylchloride) conduit as the multiconductor telecommunications cable. This telecommunications cable terminated in Building 624. It could not be determined if the telecommunications ground conductor was actually connected to a grounding electrode or if it went directly to Building 624. It was also unknown whether the PVC conduit was continuous between the buildings.

The occurrence history database indicated that Building 627 had the greatest number of occurrences with thirty-five (35) RS-232 port failures on network ports. Also having a large number of occurrences was Building 624 with 30 concentrator board failures. Recall that Building 627 has a very large earth-ground resistance on the telecommunications system (1,230 ohms) which limits protector operation and can even induce failures due to voltage potential differences. Since the concentrator in Building 624 feeds the RS-232 ports in Building 627, the concentrator failures in Building 624 are most likely directly related to the RS-232 port failures in Building 627.

A relationship similar to that between Buildings 624 and 627 exists between Buildings 1003, 924 and 802. The occurrence history database listed Building 1003 as having 30 concentrator card failures. This concentrator feeds Buildings 924 and 802. Building 924 has had fifteen (15) RS-232 port failures and Building 802 has had 8 port failures. Based on the situation at Buildings 624 and 627, one would suspect that Building 924 (and 802 to a lesser extent) has poor grounding on the telecommunications system.

Examination of failed I/O boards: The two failed I/O boards were examined. In both cases the IC chip which had exploded was the RS-232 line driver, part # MC1488. The external data lines connected to this chip are "send data" (SD), "data terminal ready" (DTR) and "request to send" (RTS).

ANALYSIS

The soil in much of the Ft. Stewart area is quite sandy and has a relatively low conductivity (high resistivity). Thus, a low resistance to ground is difficult to obtain. This fact, coupled with the high lightning frequency, practically ensures a high level of lightning-induced problems on the electrical and telecommunications systems. Since the electrical systems (and telephone systems to some extent) are more tolerant of overvoltages than data communications systems, most of the lightning-related problems occur on the data communications systems. At Ft. Stewart the same type of protection is used on the data communications system as on the telephone system - carbon block protectors. This is adequate protection for the telephone system since it is inherently more robust than the data communications system. The telephone system operates at higher voltage levels and is designed to meet certain Federal standards for overvoltage tolerance. No such mandatory standards exist for data communications systems.

It should be possible to significantly reduce lightning related data communications system damage by the use of special protective measures. The rationale for the recommendations given by USACERL is based to some extent on the protection concepts developed for the Federal Emergency Management Agency (FEMA) for Electromagnetic Pulse (EMP) protection of Emergency Broadcast Stations (EBSs) and Emergency Operating Centers (EOCs).[1]

Sensitive electronic equipment is subject to damage and upset from high voltage transients, many of which are thunderstorm related. Among these are:[2]

- A direct lightning strike to a building that houses sensitive equipment;
- A direct lightning flash to a power line entering the building via overhead or buried wires;
- A direct lightning flash to interconnecting wiring;
- A direct lightning flash to a structure, tree, or other object;
- An intercloud or cloud-to-cloud lightning flash in the vicinity;
- The presence of a charged cloud overhead;
- An electrostatic potential in surrounding air;
- Voltages induced on interconnecting lines.

The use of personal computers, both singularly and networked, has increased considerably in recent years. Unfortunately, due to commercial market economics, these sensitive electronics are typically not internally protected against power line and communication line transients. The majority of the situations examined by the USACERL team do not appear to be the result of direct flashes to system components. Thus, much of the damage seen may be preventable by the installation of additional grounding and transient suppression devices.

RECOMMENDATIONS

Electric Power and Telecommunications Grounding

The electrical power grounds and telecommunications grounds should be measured for each building where there have been lightning related problems. The National Electrical Code recommends less than 25 ohms earth-ground resistance for electrical systems.[3] Although no standards for telecommunications earth-ground values have been established many sources recommend less than 5 ohms.[4]

In addition to lightning, earth currents and voltage potential differences accompany the movement of electrical storms over an area. Voltage potential differences between systems and system components must be kept as low as possible to prevent damage and upset. The relevant systems at Ft. Stewart are the electrical and telecommunication systems. At the buildings surveyed the grounds for the telecommunications system were attached to a single ground rod located near the telecommunications system entry, while the electrical power ground was located at the power entry. Because of the high soil resistivity at Ft. Stewart these ground rods may not be at same voltage potential, even though the spacing seems small.

Due to the high resistivity of the soil in the cantonment area of Ft. Stewart, the resistance to earth of a single rod is likely to be fairly high; therefore grounding practices that are satisfactory in other areas may not provide adequate protection here. Theoretical values of resistance to earth for several ground rod configurations are plotted in Figures 1 though 3.[5] For all configurations resistance curves for three rod lengths, 2.4, 3, and 6 meters (8, 10, and 20 foot), versus soil conductivity are plotted. Vertical lines are drawn on the plots indicating the three soil conductivity values which were measured at Ft. Stewart. Figure 1 shows the theoretical resistance for a single ground rod. Note that a 3 meter rod at Building 627 is predicted to have a resistance to earth of approximately 500 ohms and approximately 300 ohms at Cottrell Field. (Recall that the measured soil conductivity was to a 2.4 meter depth. Therefore the resistance for the 3 and 6 meter rods could differ from that of the 2.4 meter length due to differing conductivities at 3 and 6 meter depths.) Curves for four identical rods in parallel are plotted in Figure 2. Now note that the predicted resistance to earth of the system of four (4) 3 meter rods is approximately 170 ohms at Building 627 and approximately 100 ohms at Cottrell Field. In Figure 3 resistance curves are plotted for multi-rod configurations where the rods are arranged along the edges of a square. In these cases using sixteen (16) 3 meter rods at Cottrell Field yields a resistance of approximately 40 ohms. It is obvious from this data that it is extremely difficult to get a low earth-ground resistance at Ft. Stewart. (One individual mentioned that a telephone ground rod had been driven 12 meters

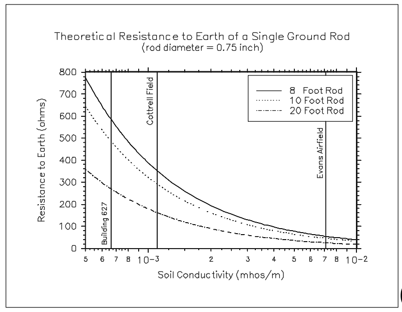

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Figure 1. Resistance to earth of a single ground rod.

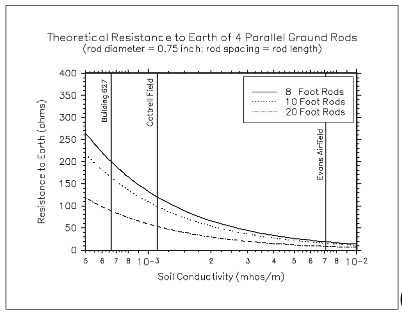

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Figure 2. Resistance to earth of four parallel ground rods.

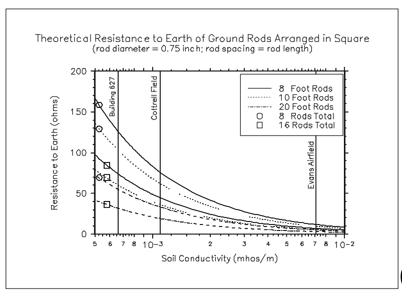

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Figure 3. Resistance to earth of ground rods arranged in a square.

(40 ft.) to get an acceptable earth connection for a telephone system at Ft. Stewart.)

Electrode enhancement through chemical salting, backfilling and increased water retention is also possible.[6] These soil modification techniques increase the effective area of the grounding electrodes. In chemical salting, ion-producing chemicals are added to the soil immediately surrounding the electrode. Large reductions in the earth-ground resistance of the electrode may be expected after chemical treatment. The disadvantages of chemical treatment are the need for retreatment every few years and the corrosive environment produced which may increase corrosion of nearby objects. In backfilling operations the soil is excavated, the grounding electrode is inserted, and then the hole filled with a more conductive and water retentive carbon-based material.

To establish as low a earth-ground resistance as possible and to prevent voltage potential differences between systems from causing problems, it is recommended that a ring ground system be installed at every building and that all existing ground rods at that building be incorporated into this system. Figure 4 depicts the concept of a ring ground system. The ground rods should be connected serially to form a ring around the building. Note that the figure illustrates that if the electrodes do not lie in a straight line the existing electrodes should still be connected into the ring in a serial manner. Bare copper wire with a minimum size of #6 AWG should be used to interconnect the ground rods. If this horizontal conductor is buried more than a foot in depth it will contribute to the overall grounding system, reducing the total

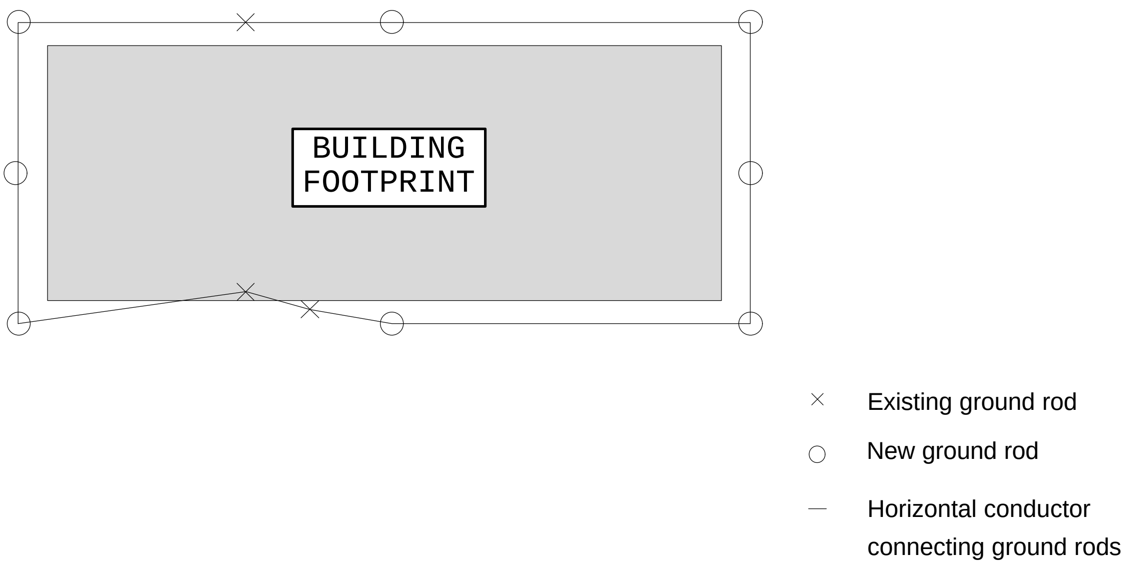

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Figure 4. Illustration of a ring ground.

resistance by about 10%.[7] If the connections between the ground rods, the horizontal conductors, and the building ground systems are all buried then all connections must be brazed or welded and protected from corrosion. All building grounding systems (e.g. electrical, telecommunications, water, lightning) should be tied to this ground system. As a minimum the grounding system should be designed according to the National Electrical Code (NEC).[8]

A building's priority for obtaining an improved grounding system should be based on the number of lightning-induced problems and earth-ground resistance measurements of the building's present ground system.

Until a proper ring ground system can be installed, it is recommended that all existing building ground systems be tied together. This will lower the voltage potential differences between the system grounds which develop as a result of thunderstorm activity. At a minimum the electrical, telecommunications, and computer network grounds should be interconnected. The ideal way to do this is to have their service entrances co-located. This, of course, will require moving one or more of the service entrances. Co-location is the preferred situation for areas of low conductivity soil, like at Ft. Stewart, because a single-point ground system can be used. (A single-point ground system will eliminate the possibility of voltage potential differences between ground systems.) The next best fix is to connect the grounds outside the building, at the ground rods. A conductor with a minimum size of #6 AWG should be used. If connecting the system grounds outside the building is not feasible then the system grounds should be connected inside the building. The best way is to run a #6 AWG or larger conductor from the telecommunications ground to the electrical system ground at the electrical service entrance. If this is not feasible then the building's existing green wire ground may be used. Because many of the buildings on Ft. Stewart have been partially rewired, it must be verified that the green wire ground has low resistance to the electrical service entrance. If resistance is **not** near zero then this method **cannot** be used and a new ground conductor must be installed. **Regardless of which method is used, the existing telecommunications ground should not be removed.** Connection points must be cleaned and stripped of any non-conductive coatings (e.g. paint) prior to making connections.

Because the earth-ground resistance of the telecommunications system at Building 627 is so great (1,230 ohms) compared to the electrical system's earth-ground resistance (1.67 ohms), the system grounds should be connected as soon as possible. Fortunately, the telecommunications system ground is within a few feet of the main electrical panel. Therefore a conductor can be run directly from the telecommunications ground to the electrical panel. There is a grounding lug on the side of the electrical panel which can be used for this purpose.

Due to building rewiring it is possible that electrical outlet polarity may not always be correct. This fact may not be important for electronic equipment with transformer type power supplies, but may cause the chassis to be "live" (excessive voltage relative to ground) on units such as personal computers (PCs) which use switching power supplies. Also, a transient voltage surge suppressor connected to that outlet may not function properly if improperly wired. To insure that these problems do not occur, each outlet used to power a PC should be checked to verify proper ac wiring.

Transient Protection for Low Voltage Data Communications Lines

The "firing" voltage (the voltage at which the protector begins to conduct current) of the carbon block protectors on the data communications system was not determined. However, since these are standard telephone type protectors the minimum firing voltage is expected to be 150 Volts. Even with a satisfactory ground this voltage is not low enough to consistently protect the communications systems electronics from lightning associated transient voltages. Thus, some additional protection should be provided on all interbuilding copper communications cables terminating at computers or at concentrators. It is essential that the protection be installed between the data line and chassis ground - **not** to the plug-in card ground. Note that the communication cable grounds are generally grounded to the computer chassis through the plug-in card and the mother board. High transient currents could damage the printed circuit traces on these boards.

Figure 5 shows a generally recommended protection circuit for low voltage data lines.[9] In this circuit A_1 represents a surge arrester, such as the carbon block protectors, R_1 represents a series resistor, L represents series inductance, and D_1 and D_2 represent avalanche diodes. The series resistance R_1 is included in the circuit to protect the avalanche diodes, D_1 and D_2, from excessive current. As the current increases through the diodes the voltage across the resistor will rise, eventually reaching the firing voltage of the surge arrester, A_1. A_1 will fire, thus shunting the current to ground ahead of the diodes. Avalanche diodes, D_1 and D_2, are often combined into a single circuit element. The series inductance, L, is not implemented as a circuit element, it represents lead and line inductance and is used for analysis of the circuit.

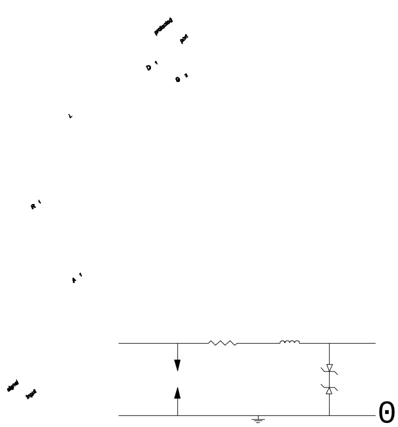

Figure 5. Protection circuit for low voltage data lines.

The Model 355 terminal protectors used at Ft. Stewart for protection of the asynchronous lines, when combined with the carbon block protectors, form a protection circuit similar to that recommended in Figure 5. Although the primary use of these protectors is to prevent any standard telephone voltages on the lines from damaging connected equipment, they offer some degree of transient protection. Unfortunately this protection is only on three of the five signal input lines. The two unprotected lines are "send data" and "receive data." Recall that the external data lines which are connected to the IC chip which exploded on the failed I/O boards are "send data" (SD), "data terminal ready" (DTR) and "request to send" (RTS). The RTS line is not used in the data communications system implementation at Ft. Stewart.

There are several commercial sources for plug-in protectors for data lines; however, their effectiveness is not known. Not all of these commercial protectors fully implement the circuit of Figure 5. The protection circuit of Figure 5 is simple enough, and the parts cheap enough, that it could be implemented by Ft. Stewart personnel and designed specifically to their system.

AC Power Protection

The installation of transient voltage surge suppressors (TVSS) on the ac power services to computer and communication electronics is recommended. Two stage power protection should be installed, with primary protection installed either at the building electrical service entrance or at the power panel serving the outlets for the equipment. This can be either individual MOVs installed as described in FEMA CPG 2-17,[10] or commercial protection units. Commercial units are likely to have indicator lights to identify failed units, however, the circuit configuration required for indicator lights, and sometimes the lights themselves may limit protection.[11] The FEMA installation technique recommends using a spare circuit breaker for installation of TVSS units. Thus a shorted unit would trip the breaker. Second stage protection can be provided with commercial surge protectors at the PC electrical power input.

The ideal TVSS configuration consists of high energy MOVs at the electrical service entrance, medium energy MOVs or high power semiconductor devices at the subpanel, and high power semiconductor devices or low energy MOV/low power semiconductor hybrids at the PC electrical power input.

Grounding of Tall Structures

All tall structures, such as control towers, antenna towers, power lines and power poles must be adequately grounded. These are the primary targets for direct lightning flashes. Proper grounding will also aid in the reduction of side flashes and lightning-related surge currents in wires and cables. Protection should be installed according to the National Fire Protection Association lightning protection code.[12]

Lightning Protection Systems for Buildings

The survey team noted that, in general, the buildings at Ft. Stewart did not have lightning protection systems. It is not known if this is an official base policy or if the protection was deleted at the time of construction for reasons of economy. While a certain degree of protection is offered to the buildings by the presence of tall trees and grounded electrical transmission lines, the USACERL team is of the opinion that building lightning protection systems are necessary for protection against direct lightning flashes. These should be installed according to the National Fire Protection Association lightning protection code.[12]

Lightning Protection for Firing Ranges

The firing ranges were not visited by the USACERL survey team, however, details of installation and control were discussed with range control personnel. The target control electronics on the firing ranges were described as being 4 to 20 mA current loops, which are susceptible to a number of problems when there is lightning activity in the area. These problems are likely to be intensified due to the general high resistivity of the soil in the area.

Additional analysis is recommended to further resolve this problem. However, the following two approaches may be considered as techniques to reduce the problems observed:

> The 4 to 20 mA control electronics can be replaced by a fiber optic link. Fiber optics are inherently immune to electrical interference problems. A complete system would consist of conversion electronics at the control and target ends of the system and installation of the fiber optic lines. Surge protection of the electrical power at both ends should also be considered.
>
> A degree of "shielding" can be provided by installing a woven wire mesh over the electrical conductors used for target controls. The mesh should be a minimum of one meter (3 feet) wide and run the length of the installed cable. Ideally it should be covered with earth to prevent its destruction by vehicles, etc. and to provide a low resistance to earth for any lightning induced currents flowing in it.

Evans Air Field

The "Thicknet" problem may have been resolved by grounding the outer conductor of the cable, however, based on the ground resistance measured at Evans Field, USACERL recommends installation of an additional ground rod in parallel with the existing one. The additional rod should be installed at a distance from the present rod not less than the maximum length of either rod. The installed earth-ground conductor drains only the cable outer conductor. There are commercially available protection devices which will conduct transients from the cable inner conductor to ground which can be easily installed in series with the cable. Note that the effectiveness of these components have not been evaluated by USACERL. Therefore no recommendations can be made.

Miscellaneous Lightning Protection

Installation of a thunderstorm/lightning detection system should be considered for some locations where protection measures either are not going to be considered or are not feasible. The detection systems could automatically shut down or disconnect critical equipment when a storm is detected.

Further Work:

The following items have been identified for further work:

When implemented, the success of any of the above outlined recommendations should be tracked. This could effectively be done by continuing the data collection for the occurrence history database. The database should be modified to add date-of-failure and time-of-failure (if possible) to the history field. A comparison of occurrences before and after implementing any form of lightning protection would show success or failure of the protection.

A more extensive investigation of the failed PC boards and components should be performed. This examination would look for which line conducted the transient into the machine. This could indicate whether the Model 355 terminal protectors were helping to reduce failures. This investigation could also include selected monitoring of data lines to determine which line is most affected by lightning activity.

A laboratory evaluation of commercial data line protection devices is recommended. At the present time the only information available about these devices is that furnished by the manufacturer.

A standardized specification for protection of data communication networks from lightning and other transients should be developed and implemented as a base wide policy.

A study to determine the correlation between lightning activity and telecommunications system problems should be performed. A commercial lightning locator service which tracks lightning occurrences by the radio frequency (RF) emissions from a lightning return stroke and records location, polarity, signal amplitude, and number of return strokes is available. If near real time data can be obtained for the computer network failures, then the lightning data from this service could be used to correlate occurrences. During the survey it was not possible to determine if each failure was the result of a lightning stroke. Instrumentation could be installed to measure wire currents and earth surface currents during lightning storm activity. This would help to determine if the observed problems are always associated with nearby lightning or if other phenomena such as charge cloud movement may be involved.

SUMMARY

Base operations at Ft. Stewart, GA have been significantly disrupted by lightning-induced upsets of electrical and electronic equipment. In most instances the equipment has experienced complete failure due to physical damage to electronic components. USACERL personnel visited Ft. Stewart to survey some of the problem areas. This was a preliminary survey intended to gather base wide information. Survey topics included, base geography, soil conditions, computer network topography, electrical and telecommunications grounding, and computer network hardware. In general, the survey was concerned with locating deficiencies that would create an environment that could allow lightning-induced electronics problems to occur. Survey results, analysis, protection recommendations and suggestions for future work are summarized below.

OBSERVATIONS

The sandy soil at Ft. Stewart, especially in the cantonment area, has a very low electrical conductivity. This requires more extensive efforts to obtain an adequate earth-ground resistance.

The electrical power and telecommunications systems grounding, while adequate for some locations, is inappropriate for the low conductivity sandy soil found at Ft. Stewart.

Transient surge protectors found in place on the data communications system are not sized properly for this low voltage, sensitive electronic system.

RECOMMENDATIONS

A low resistance earth ground should be established for the telecommunications system, especially the data communications network at each building.

Electrical, telecommunications, and computer network grounds should be interconnected at their service entrances.

Application specific low voltage protection devices should be installed on network data lines.

The grounding of each building's electrical power system at the service entrance should be improved.

A standardized specification for protection of data communication networks from electrical transients should be developed and implemented as a base wide policy.

CONCLUSIONS

The major cause of lightning induced electrical/electronic problems at Ft. Stewart, GA is inadequate grounding. The three relevant systems, electrical, telecommunications, and computer network, each has it's own ground. In most cases this is simply a standard copper-clad ground rod driven near the respective service entrance. This dislocated grounding system relies on the soil to form the electrical interconnection between systems, an unacceptable practice because of the very high resistance soil at Ft. Stewart. When renovating or installing new electrical/electronic systems, provision must be made for a low-impedance interconnection of the grounding systems. Co-location of service entrances, and use of a single-point ground, in combination with a building ring ground system is the preferred solution. The ground ring must have the ground for each conductive utility connected to it, including electrical, telecommunications, network, lightning, water. If co-location of service entrances is not possible then the interconnection should be made via the ring ground system.

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